Impact on Carbon Footprint: An LCA of Disposable vs Reusable Sharps Containers in a Large US Hospital

Terry Grimmond[*] and **Sandra Reiner**[^]
[*]Grimmond & Associates Ltd, Microbiology Consultants, New Zealand.
[^]Northwestern Memorial Hospital, Chicago, IL. sreiner@nmh.org

Correspondence: T Grimmond, 3 Tarbett Rd Hamilton New Zealand tg@gandassoc.com

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Abstract.

Introduction. Hospitals are striving to reduce their greenhouse gas (GHG) emissions. Targeting supply chain points and replacing disposable with reusable items are among recommendations to achieve this. Annually, US hospitals use 35 million disposable (DSC) or reusable sharps containers (RSC) generating GHG in their manufacture, use and disposal.

Methods. Using a life cycle assessment we assessed the global warming potential (GWP) of both systems at a large US hospital which replaced DSC with RSC. GHG emissions (CO_2, CH_4, N_2O) were calculated in metric tons of carbon dioxide equivalents ($MTCO_2eq$). Primary energy input data was used wherever possible and region-specific conversions used to calculate GWP of each activity. Unit process GHG were collated into manufacture, transport, washing, and treatment and disposal. The DSC were not recycled nor had recycled content. Chemotherapy DSC were used in both systems. Emission totals were workload-normalized per 100 occupied beds-yr and rate ratio analysed using Fisher test with $P \leq 0.05$ and 95% CL.

Results. With RSC, the hospital reduced its annual GWP by 127 MTCO2eq (-83.5%) and diverted 30.9 tonnes plastic and 5.0 tonnes of cardboard from landfill. Using RSC reduced the number of containers manufactured from 34 396 DSC annually, to 1844 RSC in year one only.

Conclusions. The study indicates sharps containment GWP in US hospitals totals 100 000 MTCO2eq and if RSC were used nationally the figure could fall by 64 000 $MTCO_2e$ which, while only a fraction of total hospital GWP, is a positive sustainable step.

Keywords: sharps containers**,** greenhouse gases**,** reusable, Sharpsmart, carbon footprint, global warming potential**,** life cycle assessment**,** sustainable, hospital.

Introduction

Hospitals account for 3% of US greenhouse gas (GHG) emissions with 54% derived from supply chain goods and services (Chung & Meltzer 2009). Most hospitals are striving to reduce these emissions and targeting supply chain points (Chung & Meltzer 2009) and replacing disposable products with reusables (WHO-HCWH 2009) are among recommendations to achieve this. Annually, we estimate US hospitals dispose of their needles, scalpels, etc, into 35 million disposable (DSC) or reusable sharps containers (RSC) and their manufacture, use and disposal are associated with the generation of GHG. A literature search revealed no journal-published studies comparing the GHG emissions of the two systems. RSC market-share in the US has risen markedly in the last decade, with sustainability, cost, and safety stated as change rationales. Plastic waste is markedly reduced with RSC, however, they are washed, heavier than DSC and transported un-nested in carts, which raises the question, "Could emissions from RSC transport and washing outweigh emissions from repeated manufacturing of DSC?" This case study addresses the question by employing a life cycle assessment (LCA) to calculate and compare each system's contribution to global warming potential (GWP) at Northwestern Memorial Hospital (NMH), an 850 bed hospital in Chicago IL, which converted to an RSC certified for 500 uses.

Methodology

Using established principles (British Standards Institute, 2008) we utilised a cradle-to-grave life cycle inventory (LCI) and product-system LCA designed for sharps containers. The tools, developed by Waterman Group UK to deliver a comprehensive and unbiased assessment of products, linked some 700 cells of information and calculations. The LCI listed all energy-using processes required by each containment system as implemented at NMH. The major life stages were: manufacture (resin and containers); transport; washing (RSC); and treatment and disposal. The LCA assessed the GWP of all energy used (vehicle fuel, gas, electricity) in these processes and in the manufacture of ancillary products necessary for each system (pallets, transport cabinets, cardboard, wash products, etc).

We calculated each system's GHG emissions (CO_2, CH_4, N_2O), expressed in metric tonnes of carbon dioxide equivalents ($MTCO_2eq$) for 12 months before and after NMH's conversion from polypropylene DSC (BD, Franklin Lakes NJ) to the RSC (Daniels Sharpsmart Inc, Chicago IL). At transition, all DSC were swapped for RSC and an additional 12 RSC were fitted. The mean fill line litre capacity of DSC containers was 10.9 and was 18.0 for RSC. Identical changeout protocols for full containers were carried out by NMH for DSC and external contractor for RSC. The DSC were manufactured in Oceanside CA using mainly windfarm-sourced electricity and delivered unassembled and nested in cardboard containers (recycled by NMH) on wooden pallets. The RSC were manufactured in Greenville MI using coal-generated electricity and delivered assembled in reusable transporter cabinets constructed from metal and plastic. Upon delivery to the Gary IN processing plant: full biohazardous DSC were autoclaved and landfilled without shredding; chemotherapy DSC (CDSC) transported and incinerated at waste-to-energy incinerator; full RSC robotically opened, decanted and decontaminated and contents autoclaved (at same factory) and landfilled. Resin production was offshore for RSC and in US for DSC. The distance from container manufacturing plant to NMH was 3298 km for DSC and 656 km for RSC. The distance from processing plant to NMH was 58 km. Wastewater from RSC processing was piped to drain and subject to state requirements for trade water discharge.

The following data sources were used in calculating GHG: American Chemistry Council data (American Chemistry Council 2010) and Plastics Europe (Plastic Europe 2005) for DSC and RSC resin manufacture respectively; actual primary energy input data for RSC container manufacture, RSC washing, DSC autoclaving, and for RSC and DSC transport vehicles and distances; US industry data (B Bronsink, personal communication) for DSC container manufacture; California and Michigan USEPA eGrid values (USEPA 2011) respectively for GWP impacts of DSC and RSC container manufacture; GaBi data (PE International 2006) for energy inputs for transport, water supply and treatment, incineration, and manufacture of wash product, cardboard and steel; and Franklin and Associates (Franklin & Associates 2009) for pallet GHG. The same database and values were identically applied to the relevant unit processes in both container systems. In both systems, the manufacture, treatment and disposal of CDSC were included. Processing of container contents was identical in both systems and excluded. The RSC is certified for 500 uses and 2% annually require dismantling and repair with 80% of parts reused and 20% recycled. RSC manufacturing emissions were divided by their anticipated life expectancy (British Standards Institute, 2008). In accord with product LCA principles, infrastructure and assets were excluded from both systems. The GHG associated with manufacture of ancillary reusables (transport cabinets and pallets) were included and calculated using their expected life span. The DSC were not recycled nor had recycled content. Data on size, brand and number of containers, occupied beds (OB) and costs were obtained from NMH. Tare weights of all DSC were determined by weighing. The transition month was excluded to avoid data overlap. Energy values for hospital-to-plant transport, autoclaving, processing, and plant-to-landfill transport were compared with accuracy as the same contractor hauled and processed DSC and RSC and both systems were processed at, and hauled to, the same factory and same landfill. Internal review was waived by NMH bioethics committee. Emission totals were workload-normalized per 100 OB-yr and rate ratio analysed using Fisher test with $P \leq 0.05$ and 95% CL.

Results

Use of RSC reduced sharps management GWP at NMH by 127 MTCO2eq (-83.5%). In the baseline year 34 396 DSC were manufactured from 32.1 tonnes of plastic and required 5.02 tonnes of corrugated cardboard packaging. At disposal, 30.9 tonnes of plastic was landfilled and 1.2 tonnes incinerated (Table 1). Excluding operation of landfill machinery, landfilled plastic was accorded zero GWP (USEPA 2010). In RSC year: occupied beds rose 9.6%; 1842 RSC were manufactured (year one only); 37 RSC required repair with 19 kg parts being recycled or reused (nil to landfill); with recycling credit (USEPA 2004) an equivalent of 1.6 RSC were manufactured as replacement containers (i.e. 1844 total). In the 12 month RSC period, 23 891 container exchanges occurred (including 637 CDSC) and the RSC, certified for 500 uses, were reused an average of 12.6 times, giving an "end-of-life" of 39.6 years.

Table 1: Annual waste and GHG comparison: disposable vs reusable sharps containers at NMH.

	DSC	**RSC**
Containers Manufactured	34 396	2481[a]
Containers landfilled	33 759[b]	47[c]
Weight plastic landfilled (kg)	30 920	123[c]
Weight cardboard boxes (kg)	5020	116[d]
Containers exchanged	34 396	23 891
MTCO2eq GWP[e]	139.1	25.1
Occupied Beds	574	629
$MTCO_2eq$ GWP per 100 OB-year[f]	24.2	4.0[g]

GHG, Greenhouse Gas; NMH, Northwestern Memorial Hospital; $MTCO_2eq$, metric tonnes carbon dioxide equivalent; DSC, disposable sharps container; RSC, reusable sharps container; OB, Occupied Beds.

[a] 1844 RSC in year one only, then 637 chemotherapy DSC annually thereafter.

[b] Chemotherapy DSC are incinerated.

[c] In reality no RSC were landfilled as all parts were either reused or recycled. However the table shows number and weight apportioned annually over RSC "end of life" of 39.6 years.

[d] Chemotherapy DSC packaging.

[e] Emissions of GHG expressed in terms of global warming potentials, defined as the radiative forcing impact of one mass-based unit (kg) of a given GHG relative to an equivalent unit of carbon dioxide over a given period of time (100 years) (British Standards Institute 2008).

[f] One hundred Occupied bed years used as workload denominator to normalize base year comparison and facilitate interhospital comparisons.

[g] 83.5% reduction; $P < 0.001$; Rate Ratio = 6.31; CL = 3.95-10.57.

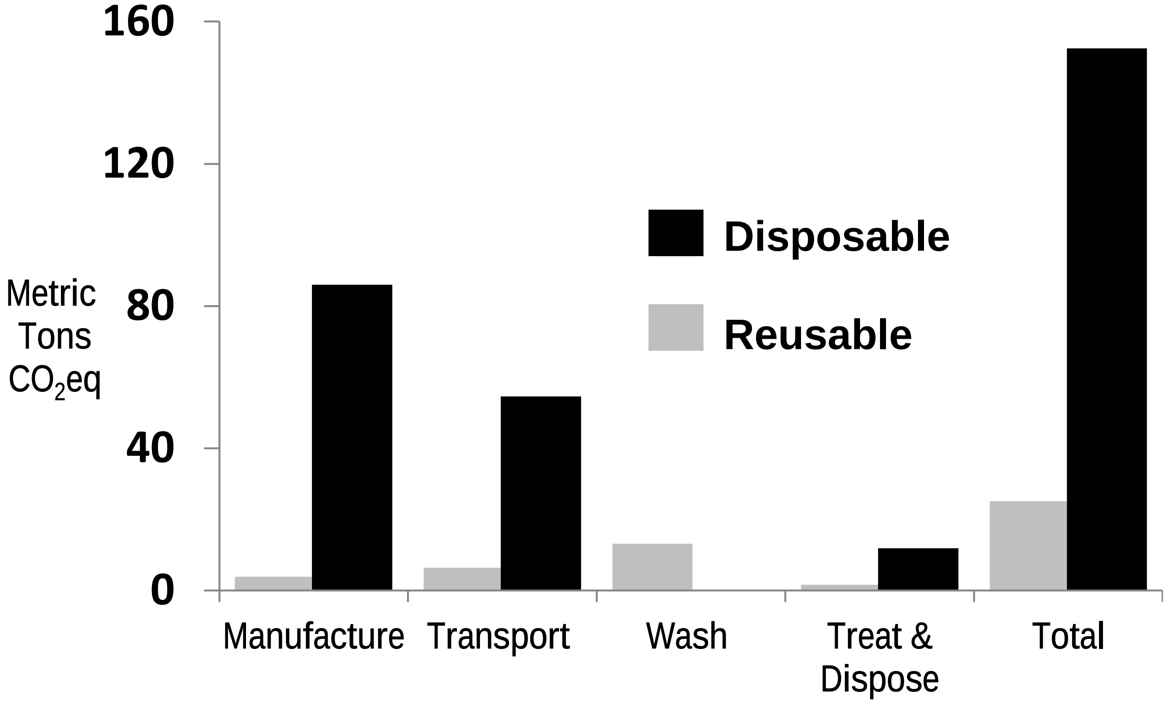

Figure 1: Annual greenhouse gas emissions by life stage of disposables and reusable sharps containers at NMH, normalised to occupied beds.

Discussion

Reusable sharps containers are common in USA and Australia where they have been used since 1986, and in the last decade have been increasingly used in UK, New Zealand, Canada and South Africa. Generally constructed of tougher material, RSC design can be identical to DSC and subject to identical tests in standards (Canada Standards Association 2007). In the US: incineration of DSC with energy capture is used for approximately 10% of sharps waste (chemotherapy, pharmaceutical); around 85% are decontaminated by non-incineration technologies (predominantly autoclaving) and landfilled; a few percent of DSC are decontaminated and used as calorific fuel; DSC with recycled content (commonly up to 20% of content) are increasing in availability and may account for 5% of DSC sold; recently materials reclamation of DSC and their contents has become available and with greater commercial viability will be increasingly adopted by DSC and RSC users.

To protect users and handlers, the US Food and Drug Administration clears for market all sharps containers and requires manufacturers to prove that their container meets the US Occupational Safety and Health Administration's standard as well as complying with a comprehensive sharps container standard. Prior to such testing, if a manufacturer states an RSC can be used 500 times it must be robotically opened, closed and decanted of sharps 500 times, and pass the US Department of Transportation's vibration test. Generally RSC are reused on average 10-15 times per year and with rugged construction and effective inspection and repair, can last many decades. In the US the majority of states allow use of sharps containers until full and do not set "maximum days in use".

The fill line capacity of US patient-room sharps containers has doubled from approximately 6 to 12 litres in the last decade, due mainly to lower costs, reduced labour, and increased safety (Grimmond et al, 2010). The DSC and RSC used at NMH were the largest patient-room sizes commercially offered by their respective manufacturers and the study is therefore a true comparison of the two containment systems as applied at NMH.

Figure 1 shows that manufacturing (of resin and containers) gave the largest differential between the two systems and is a function of: resin weight (32.1 tons annually for DSC and 4.9 tons in year one for RSC); container manufacturing (related to resin weights); and low annual RSC manufacturing emissions due to their extended life span. The second largest differential was transport due not to the hospital-processing plant distance, but to the large distance the DSC had to be transported from their manufacturing plant to NMH (3298 km vs RSC's 656 km). In this study the geography of the two supply systems favoured RSC. We recalculated GWP of both systems in a reverse scenario (hospital in Los Angeles; DSC manufacturing plant at 133 km and RSC at 3636 km) and the GWP reduction with RSC decreased from 83.5% to 64.5%. Thus distance is important; however manufacture remained the greatest contributor to DSC GWP.

Collation of unit processes into their 4 life stages (Figure 1) revealed that, with RSC, decanting and washing contributed 52.5% of the system's total GWP with transport, manufacture, and treatment-disposal respectively contributing 25.5%, 15.4% and 6.6%. With DSC, manufacture of the 34 396 containers contributed 56.4% and transport and treatment-disposal respectively contributed 35.8% and 7.8% of the system's GWP. In absolute terms, DSC treatment-disposal emissions were 6.5 times that of RSC due to the mass of DSC autoclaved vs zero RSC autoclaving (CDSC included in both systems; "end-of-life" transport to landfill included in RSC).

The RSC, with 65% larger size, had less container exchanges and labour. To test the impact of an equal-sized DSC we re-calculated the GWP with DSC of same RSC size and exchanges, i.e. 65% larger (45% heavier) and 23 891 exchanges. With this scenario, DSC GWP fell <3% because, although 23 891 exchanges generated less transport GWP from hospital to plant, this was neutralised by the increased GWP generated in the extra resin production, the manufacture of heavier containers, and the transport of heavier containers from manufacturer to hospital.

A sensitivity analysis showed that in addition to the affect of distribution distances, "cleanliness" of electricity sources (e.g. windfarm vs coal) can alter manufacturing GWP by 15% across US grids. Increasing vehicle load capacity from 75% to 100% (if feasible) had <5% reduction on Total DSC GWP. Shredding of all DSC (nil in study) altered GWP by <0.2%. Water usage in RSC processing was associated with 40% of this process' GWP and efforts to reduce water volumes would lower GWP. Finally, as stated earlier, energy and material reclamation will markedly reduce manufacturing GWP in both systems particularly if reclaimed plastic is used to offset virgin resin use. The focus of the study was GWP however in terms of the cost and safety rationales mentioned earlier, NMH costs (containers and disposal) were reduced by 19.2% with the RSC. Sharps injuries (SI) were not studied but in a separate study the RSC was associated with significant SI reduction (Grimmond et al. 2010).

The percentage reduction in NMH's sharps management GWP using RSC exceeds the 28% target required of US federal hospitals by 2020 (White House 2009) and the 80% target required of UK hospitals by 2050 (NHS 2009).

Averaging the results of this study and the results if the DSC and RSC plants were geographical reversed, and using a DSC:RSC market share of 60:40, we estimated the total GWP associated with sharps containment and disposal in US is approximately 100 000 MTCO2eq per annum and that if RSC were used in all US hospitals then a saving of 64 000 MTCO2eq may be expected. While only a small fraction of the 115 million $MTCO_2eq$ generated by hospital supply chain emissions (Chung & Meltzer 2009), it is a positive sustainable step.

Conclusions

- At NMH, RSC significantly reduced GWP over DSC with manufacturing and transport the major contributors to DSC GWP.
- Larger containers have little GWP impact however transport distances and electricity cleanliness are important factors.
- Further studies are required to reflect variations in energy and material recovery, recycling and logistics.

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Conflict of Interest

SR declares no conflict of interest. TG is a consultant in sharps injury prevention, and the healthcare sustainability and waste industries and one of his clients produces the reusable device studied in this paper. The client did not initiate, fund, review, sight or have any input into the conduct or write-up of the study.

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